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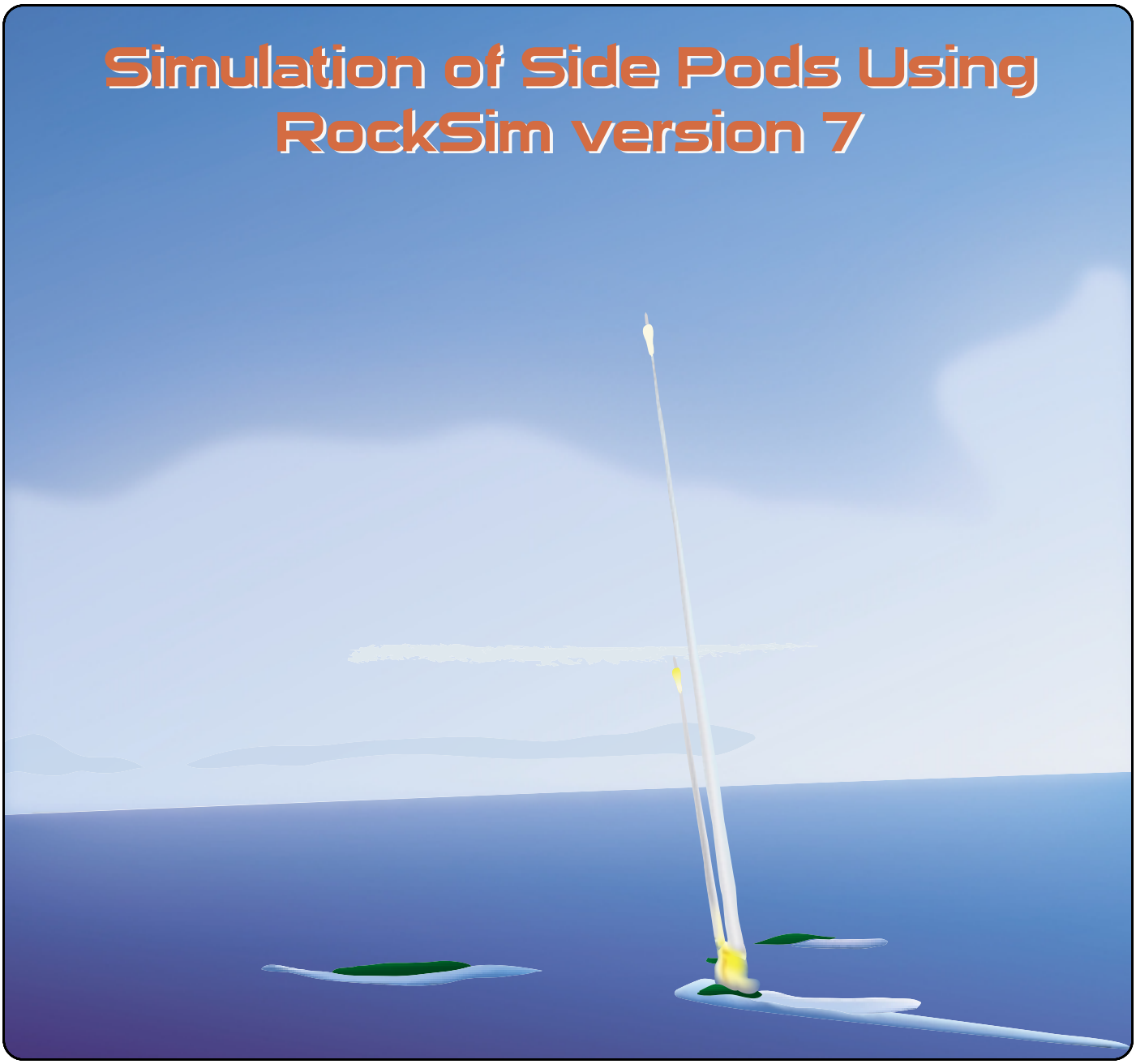
APOGEE PEAK OF FLIGHT NEWSLETTER

Simulation of Side Pods Using RockSim version 7



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Simulation of Side Pods Using RockSim Version 7

By Bruce S. Levison

Bruce S. Levison has asked us to share this article with other RockSim users. It describes a method that he feels will help to simulate side pods, ring tails and tube fins using the concept of a fin mount in RockSim. Bruce feels that the CP will be in the right location on the rocket. Please note: The user assumes all risk for the information obtained with this method.

Download the RockSim design files at: http://www.ApogeeRockets.com/Education/downloads/sidepod.zip. After downloading and unzipping, place these files in the Design folder within the RockSim Folder on your hard drive. These files cannot be viewed using the demo version of the RockSim software.

The fin mount concept was introduced in my *Simulation Fins on Fins* article (see issue #113 of the Apogee Peak of Flight Newsletter, October 27, 2003 http://www.apogeerockets.com/education/downloads/Newsletter113.pdf) it allows for the easy simulation of both open and closed tubular surfaces on model rockets. Please refer to my previous tube and ring fin simulation articles to find out how these objects had been simulated using earlier versions of RockSim (see: *Simulating the effects of Tube Fins with RockSim* http://www.apogeerockets.com/simulating_tube_fins.asp and *Simulation of Ring Fin Designs Using RockSim Ver 4.0* issue #27 of the Apogee's Model Rocketry E-Zine, 11/5/00 http://www.apogeerockets.com/education/newsletter27.asp)

The central idea of my ringtail and tube fin articles is to accurately take into account the surface area of the open tube exposed to the air stream, which amounts to the "wetted" surface of the tubes. For tube fins, I previously suggested that: tube fins can be simulated as three flat fins that have the same area as the lateral cross sectional area of the tube fin (**figure/simulation 1**). For a ringtail design, I suggest simulating a ring fin as six flat fins that have a span equal to the radius of the ring fin and a height equivalent to that of the open tube (**figure/simulation 2**).

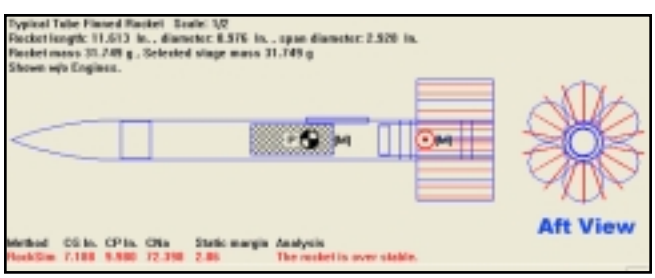

Figure 1.

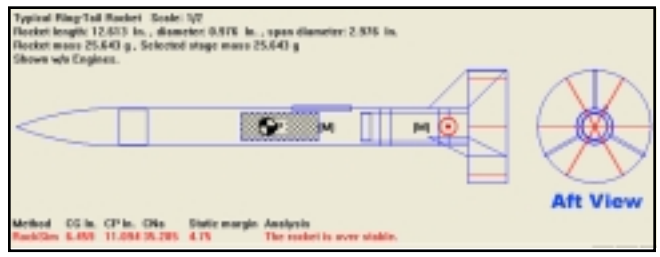

Figure 2.

If you calculate the wetted surface area (ignoring the small frontal area) of either a ringtail or tube fin you get: $A_w = 2*pi*r_o*h + 2*pi*r_i*h = 2*pi*h*(r_o + r_i)$ where r_o = outer radius of the tube fin or ring tail, r_i = inner radius of the tube fin or ring tail and h = height of the tube fin or ring tail. You have to account for both the inner and outer surfaces of the tube fins or ringtail since air moves through them contacting or wetting both sides. For these simulations since the ringtail or tube fin walls are very thin then we can set $r_o = r_i$ and estimate the wetted surface area A_w to be: $A_w = 2*p_i*h*(r_o + r_o) = 4*p_i*h*r_o$.

For the tube fins, since $r_o = d_o/2$, this gives $A_w = 4*p_i*h*d_o/2 = 2*p_i*h*d_o$ if you round pi off to 3 then $A_w = 2*3*h*d_o = 6*h*d$ where d would be the diameter of the tube. For three flat fins that have the same shape as the lateral cross section of the tube fin the wetted area would be $A_w = 2*(3*h*d)$ where the factor of two is for both sides of the flat fin.

For the ringtail the six flat fins that have a span equal to the radius of the ring fin and a height equivalent to that of the open tube the wetted area would be $A_w = 2*6*h*r_o$ again the factor of two is for both sides of the flat fin. Since $2r_o = d_o$ (or d) substituting d for $2r_o$ gives $A_w = 2*(3*h*d)$. Thus, both the tube fin and ring fin simulations account for most of the wetted surface area of the actual fins. The major error is due to rounding pi to 3, which is 0.14/3.14 * 100% or about 4.5 %. The rocket motors typically used in this hobby are manufactured to a 20% tolerance so this error in rounding pi to 3 shouldn't matter much.

You might be wondering what this has to do with side pods or the new version of RockSim. Since I shown how you

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Side Pods

Continued from page 2

can construct and use fin mounts to position fins off the central axis of the body tube, you can simulate ring or tube fins as six flat fins that have a span equal to the radius of the tubular fin and a height equivalent to that of the open tube, these fins are placed evenly in a radial fashion (like spokes on a wagon wheel) about a fin mount through the central core diameter of the tube see **figure/simulation 3** for the tube fin case and **figure/simulation 4** for the ring fin case. Note that nothing has changed for the ring fin case since the fins for this equivalent construct are already placed in a radial fashion about the central axis of the main body tube.

This new method for estimating the CP of a tube fin gives a more conservative estimate (more forward location) for the

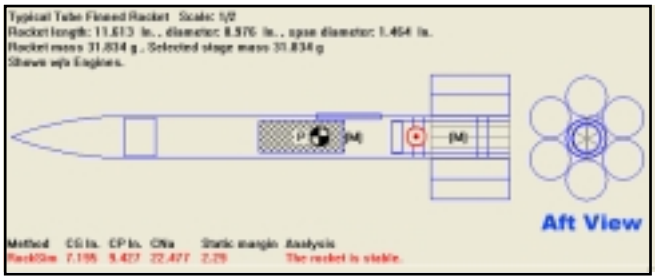

Figure 3.

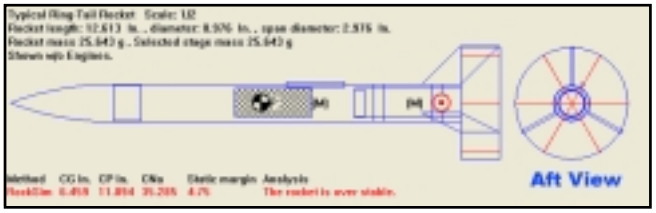

Figure 4.

CP value. This is due to having more fin area closer to the main body tube (notice that there are only six fin tips at the full radial distance of the tube fin) hence less restoring force where as the old simulation method placed more fin area farther from the main airframe body tube (notice that there are 18 fin tips at the full radial distance of the tube fin) which translates into more restoring force and a CP located more aft. In this new simulation technique for tube fins the wetted surface of the simulation construct more closely matches that of an actual tube fin and thus should be more accurate.

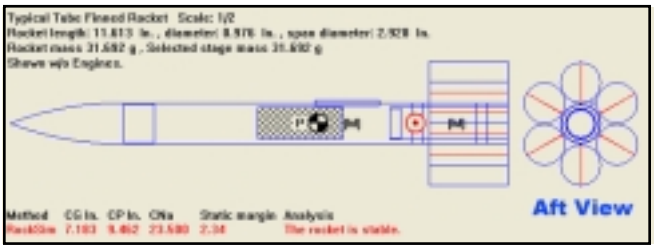

Figure 5.

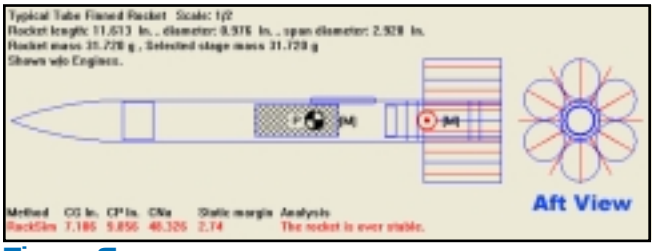

Figure 6.

But if you look at my original argument for using three flat fins to represent one tube fin one thing becomes immediately obvious; this new method for estimating the CP of tube fins is much closer to the simulation using one fin of the same lateral cross sectional area to represent the tube fin than three flat fins, see **figure/simulations 5 and 6**. The difference in the predicted CP vales using the old and new techniques amounts to about 14 mm or about 9/16 of an inch on this example.

However, the fins within these new side pod tube constructs were created at the same fixed radial angles. Spacing each subsequent fin set in each successive tube a constant radial angle apart shows that the CP value reaches a maximum when the fins for successive tubes are evenly spaced apart; at a radial angle of 10 degrees for six tube fins, see **graph 1.** Since these flat fins are representing tubular structures, the particular radial angle of the flat fins should not matter. I suggest using the radial angle obtained from incrementing the radial angle between the tube fin sets until the CP reaches its maximum see **figure/simulation 7.** Even at this maximum the new CP value is still about 1/2 inch from the three flat fins

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Side Pods

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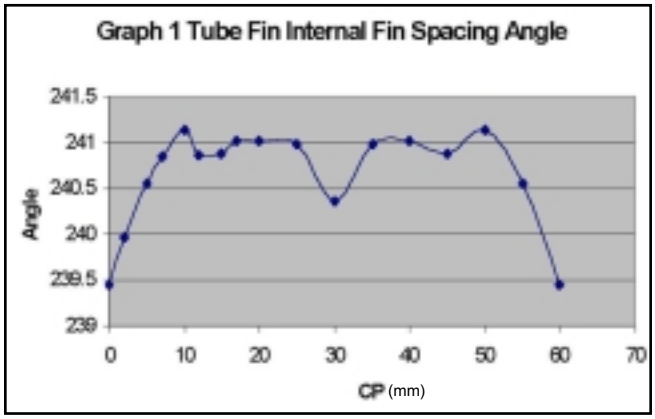


Graph 1.

construct and more closer to the one flat fins case **figure/simulation 5** than the two flat fin equivalent **figure/simulation 6.** All that can be said is, a half-inch is not much difference in the CP on a 12-inch rocket and these two different techniques will have to wait for future experimental confirmation.

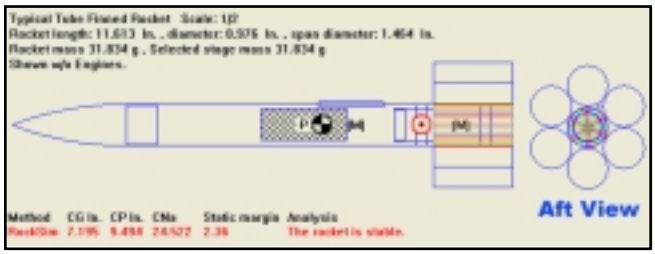


Figure 7.

The outer tube fins, which were originally inside tubes, serve to locate the CG of the tube fin. The thickness of the fins that are used for simulating the CP for tube fins is the same as the thickness of the tube fins. This is equivalent to the difference between the inside and outside radii or (r_o - r_i). Since the radial fins within the tube fin have the same wetted surface and thickness (and hence frontal surface) of the actual side pod tube they should also predict both the correct CP and coefficient of drag or C_d. A mass override of 0.001 oz is chosen for these fins so they won't affect the CG value see simulation 3.

This leads us into the case of side pods. Since air can't flow through side pods these structures only have half the wetted surface area of a tube or ring fin or just A_w = 2*pi* r_o*h. Rounding pi off to 3 gives A_w = 2*3* r_o*h which is exactly half of the estimated wetted surface of the tube or ring

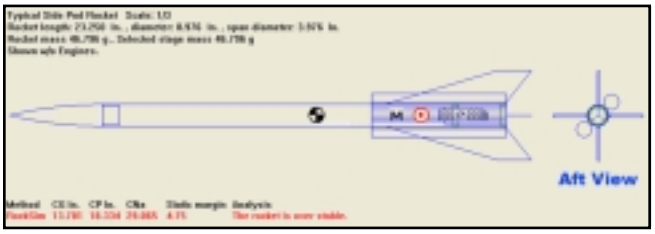


Figure 8a.

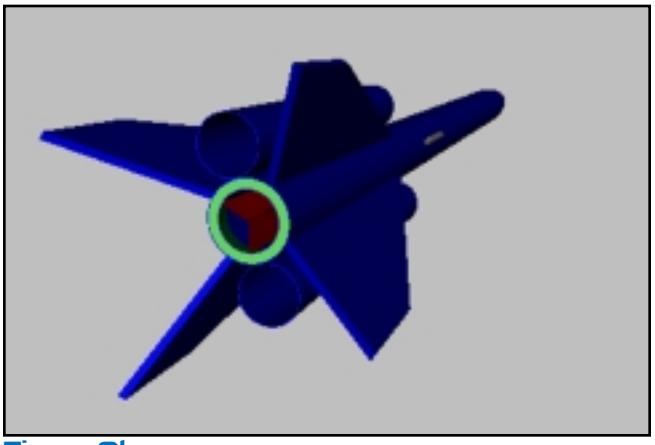
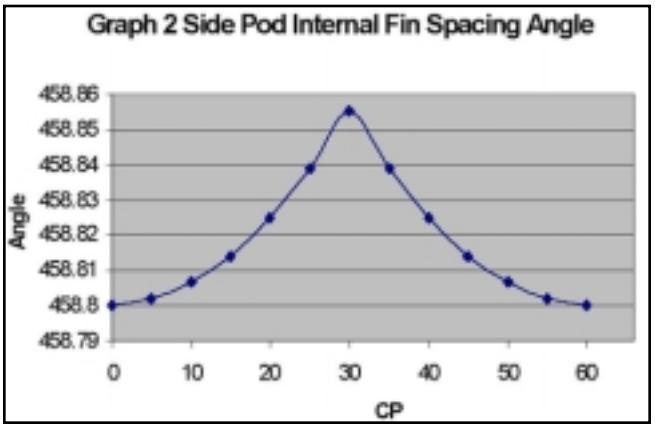


Figure 8b.

fin. This means you could simulate side pods as three flat fins (as opposed to six for open tubular fins) that have a span equal to the radius of the side pod with a height equivalent to that of side pod tube with the fins placed evenly in a radial fashion about a fin mount through the central core diameter of the side pod tube, see **figure/simulation 8**. These three fins take into account most of the wetted surface area of the side pod tube so RockSim can calculate a fairly accurate CP.

However, the fins within these new side pod tube constructs were created at the same fixed radial angles. Spacing each subsequent fin set in each successive side pod a constant

Continued on page 5



Graph 2.

Side Pods

Continued from page 4

radial angle apart shows that the CP value reaches a maximum when the fins for successive tubes are evenly spaced apart; at a radial angle of 30 degrees for two side pods in this case see **graph 2**. Since these flat fins are representing tubular structures the particular radial angle of the flat fins should not matter. I suggest using the radial angle obtained from incrementing the radial angle between the side pod fin sets until the CP reaches its maximum see **figure/simulation 9.**

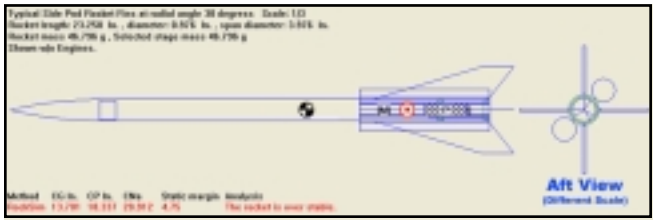


Figure 9a.

But what about placing a nosecone on top of the side pods? RockSim can be tricked into doing this using a transition constructed as the equivalent for a nosecone. The way to do this is to build transitions assigned to the side pod tubes (don't worry about their location yet) that have very narrow forward diameters, 0.001 inch, with a lengths and diameters equivalent to that of the nosecones on the side pods. Shoulder lengths and diameters should also be entered for the transitions that are equivalent to the dimensions of the nosecones.

The next step involves saving this RockSim file and changing the radial location, radial angle and location from the top of the tube the side pods are attached to (Xb) for the transitions to correspond to that of the actual side pod

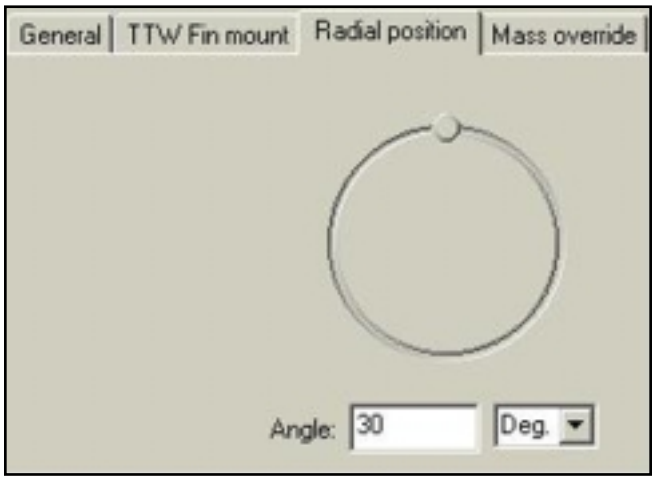


Figure 9b.

nosecones using a word processor. Since RockSim uses millimeters for the Xb values you need to determine the location of the tip of the side pod nose cone in millimeters from the top of the body tube the side pods are assigned to. One way to do this is under application settings on the units tab in the RockSim program set to Display lengths in: Millimeters. Open the main tube and write down its length in millimeters then subtract the length of the side pod and side pod transition nosecone (ignoring the shoulder) both in millimeters to give the value for Xb.

For and example, use the word processor to change (edit) the line: `<Xb>0.</Xb>` to: `<Xb>232.791</Xb>`, `<RadialLoc>0.</RadialLoc>` to `<RadialLoc>21.7424</RadialLoc>`, and `<RadialAngle>0.</RadialAngle>` to `<RadialAngle>0.785398185</RadialAngle>` for each of the transitions. You will have to do some hunting for these program lines in the transition. You can use the find (or search) function of the word processor to look for the `<Transition>` and scroll down. The radial location and angle for the transition nosecone should be set to the same values for the side pod tube as shown below.

Change:

```
<Transition>
    <PartMfg>Custom</PartMfg>
    <KnownMass>0.</KnownMass>
    <Density>1049.2093265</Density>
    <Material>Polystyrene PS</Material>
    <Name>Side Pod Nosecone</Name>
    <KnownCG>0.</KnownCG>
    <UseKnownCG>0</UseKnownCG>
    <Xb>0.</Xb>
    <CalcMass>6.79150881426269</CalcMass>
    <CalcCG>33.4819543862979</CalcCG>
     <WettedSurface>2.8496627866633e-003</
        WettedSurface>
    <PaintedSurface>2.8496627866633e-003</
        PaintedSurface>
    <GlueJointLength>0.</GlueJointLength>
    <DensityType>0</DensityType>
    <PartNo></PartNo>
    <PartDesc></PartDesc>
    <RadialLoc>0.</RadialLoc>
    <RadialAngle>0.</RadialAngle>
    <Texture></Texture>
```

to:

```
<Transition>
    <PartMfg>Custom</PartMfg>
    <KnownMass>0.</KnownMass>
    <Density>1049.2093265</Density>
    <Material>Polystyrene PS</Material>
```

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Side Pods

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```
<Name>Side Pod Nosecone</Name>
<KnownCG>0.</KnownCG>
<UseKnownCG>0</UseKnownCG>
<Xb>232.791</Xb>
<CalcMass>6.79150881426269</CalcMass>
<CalcCG>33.4819543862979</CalcCG>
 <WettedSurface>2.8496627866633e-003</
    WettedSurface>
<PaintedSurface>2.8496627866633e-003</
    PaintedSurface>
<GlueJointLength>0.</GlueJointLength>
<DensityType>0</DensityType>
<PartNo></PartNo>
<PartDesc></PartDesc>
<RadialLoc>21.7424</RadialLoc>
<RadialAngle>0.785398185</RadialAngle>
<Texture></Texture>
```

The Radial Location and Radial Angle values are the same as the side pods CG tube!

```
<BodyTube>
    <PartMfg>Estes</PartMfg>
    <KnownMass>0.</KnownMass>
    <Density>1121.29241</Density>
    <Material>Paper</Material>
   <Name>Side Pod Body tube CG only</Name>
    <KnownCG>0.</KnownCG>
    <UseKnownCG>0</UseKnownCG>
    <Xb>304.8</Xb>
    <CalcMass>3.25538835061428</CalcMass>
    <CalcCG>76.2</CalcCG>
    <WettedSurface>0.</WettedSurface>
    <PaintedSurface>0.</PaintedSurface>
    <GlueJointLength>0.</GlueJointLength>
    <DensityType>0</DensityType>
    <PartNo>EST 3085</PartNo>
    <PartDesc>BT-20</PartDesc>
    <RadialLoc>21.7424</RadialLoc>
    <RadialAngle>0.785398185</RadialAngle>
    <Texture></Texture>
```

Save the file in the same format, and close the word processor program. Re-open the modified file in RockSim and view the *Rocket design components* tab, see **figure/simulation 10.**

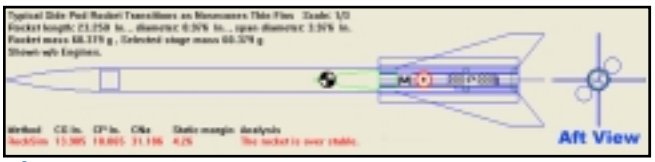

Figure 10a.

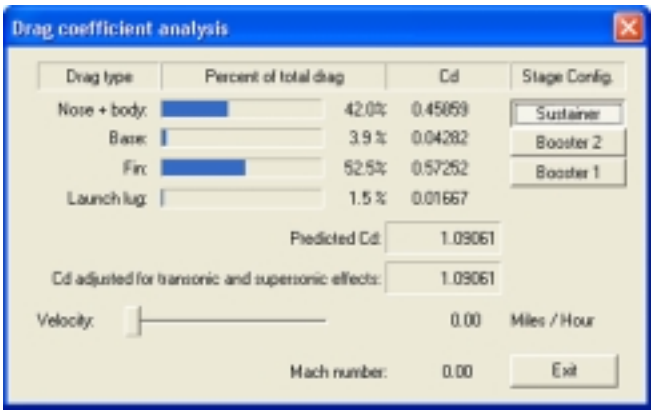

Figure 10b.

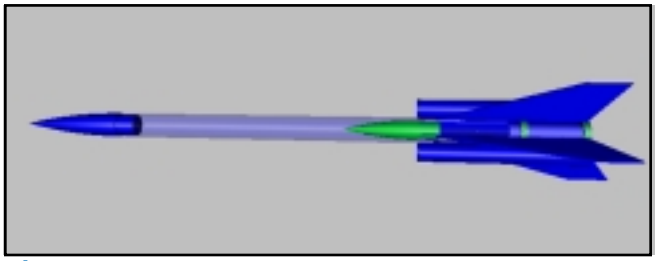

Figure 10c.

Also notice that these transitions as well as the outboard fins, within the side pod or tube fin, are located along the centerline in the 3D drawing even though the calculations of the CP use the radial angles and locations of the transitions location. This is because "The fin (or part) positioning code assumes that all fins (or parts) are radius lines from the center of the airframe." as per Paul Fossey, RockSim's creator and programmer.

These transitions help locate a better CG and CP for the rocket. RockSim will not recognize the effects these transitions and the side pod tubes have on the C_d of the rocket. The side pod tubes, which were originally inside tubes, serve only as constructs to locate the CG of the side pod. The thickness

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Side Pods

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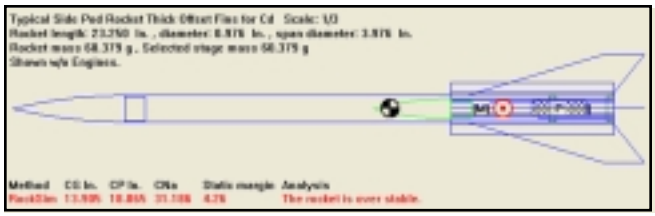

Figure 11a.

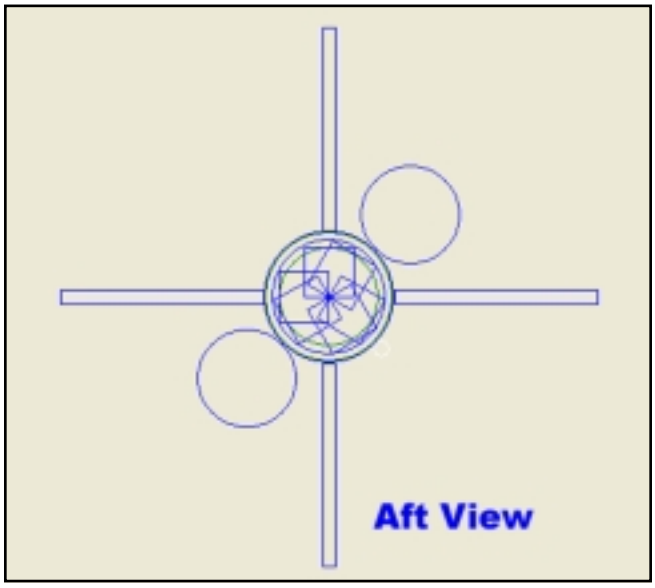

Figure 11b.

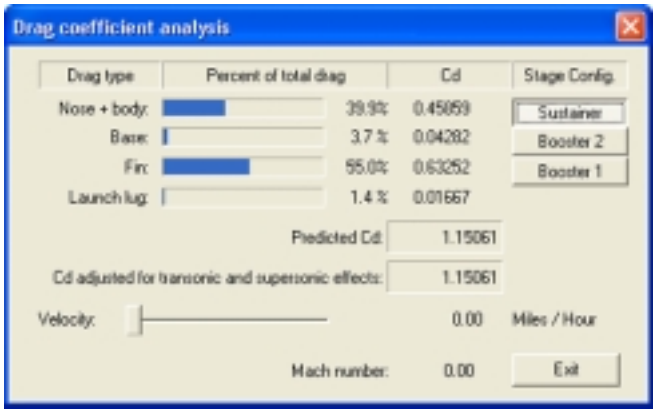

Figure 11c.

of the fins that are used for simulating the CP for the side pods should be set to be the same as the radius of the side pod to estimate the C_d of the side pod and its nosecone. The frontal area of the side pod is $A_f = pi*r_o^2$ (if the end was flat). Since

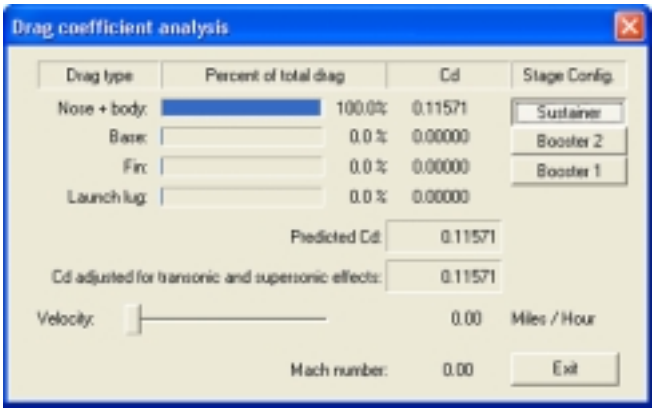

Figure 12.

the fin spans are already ro setting the fin thickness to r_o gives r_o^2. There are already three fins specified and since you could round pi to 3 then the full frontal area of the side pod is covered in the simulation to estimate its C_d see **figure/simulation 11.**

The regular ogive 18mm nosecone alone (**figure/simulation 12**) has a C_d value of 0.11571. The RockSim predicted C_d of the model without side pods (**figure/simulation 13**) is 0.95427 adding the two nosecones would give 0.95427 + 2*0.11571 = 1.18569 with the fin thickness set to r_o, the C_d is 1.15061. See **figure/simulation 11** which should be close

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Figure 13a.

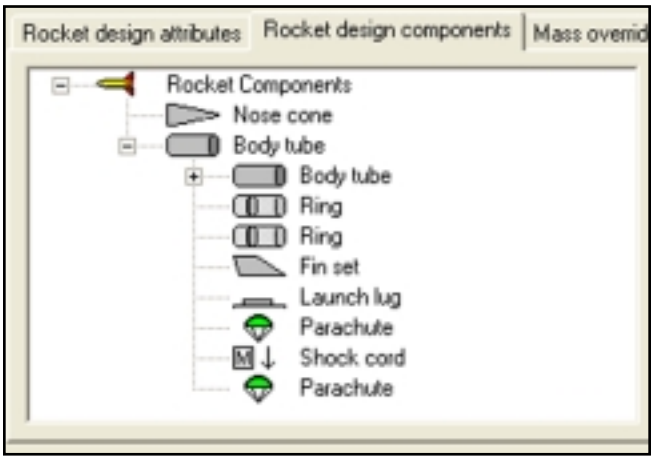

Figure 13b.

Side Pods

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enough for the simulation of this rockets flight. If you vary the shape of the nosecone you will notice that is C_d value varies from 0.09 conical to 0.17 power series shape control = 0. The fin thickness could be adjusted up or down to match the C_d value for the nosecone and or side pods if this value is known. Another option if the C_d value of the added side pod is known would be to use a fixed C_d value on the *Rocket Design Attributes* menu tab.

This article introduces the use of fins on fin mounts to simulate the CP and Cd of side pods, ring fins and tube fins. The versatile location of the fin mount construct allows it to be situated at the central diameter of these tubular structures, fins assigned to the fin mounts, six for open tubes and three for closed tubes, give estimates for the CP and Cd values of the ring or tube fins and side pods respectively. CG values can be simulated for these tubular structures can be simulated from inside tubes with a specified radial location and angle that are converted into outside tubes using a word processor.

In closing I must again mention that this simulation work is only a theoretical approximation that has yet to be confirmed with real flight data; use this unproven technique at your own risk.

I welcome any comments and criticism on this work.
Bruce S. Levison, NAR #69055

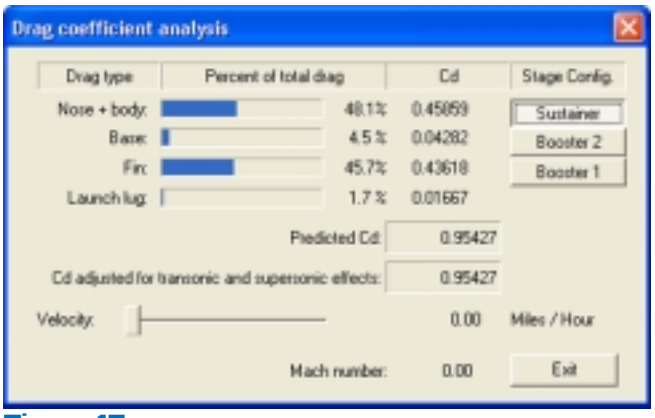

Figure 13c.

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Bruce S. Levison (NAR #69055, MTMA #606) is a rocketeer from Ohio, and a member of the National Association of Rocketry (NAR). He has published numerous articles on model rocketry, related to the many practical aspects of the hobby. Bruce enjoys tricking the RockSim software into performing simulations of non-standard rocket designs. You can usually find him helping other people with their simulation problems in *"The Rocketry Forum"* at: http://www.rocketryforum.com/ (be sure mention RockSim in the title of you post). Bruce earned an advanced degree in chemistry, and works as a research scientist at the Cleveland Clinic Foundation.

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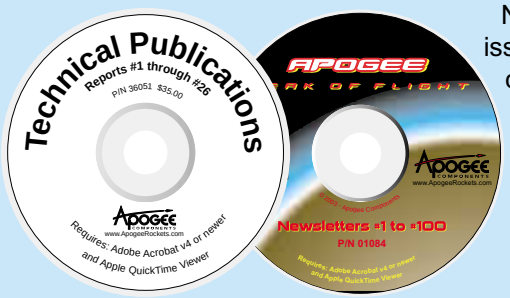

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